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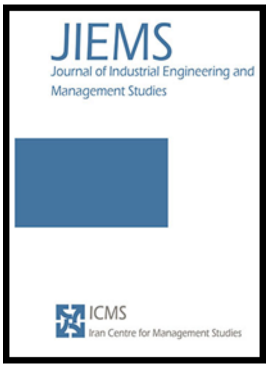

Supply chain master planning considering material-financial flows

Faezeh Motevalli-Taher[1], Mohammad Mahdi Paydar[2,*]

Abstract

In this study, tactical decisions considering the material and financial flows in a supply chain have been made. To achieve these aims and some effective solutions, a multi-objective mathematical model proposed for an integrated supply chain master planning problem. The multi-product, multi-period and capacitated supply chain network has three objective functions. Two first objective functions are maximizing the net present value of manufacturing centers and suppliers' cash flow, and the third one minimizes the market price of the final product. Besides we considered the market price as a key variable in the model and investigate its effects. Then, improved multi-choice goal programming is used to transform the multi-objective model to its single-objective one. To find out the appropriateness of the proposed model, the results of an industrial example are illustrated, and sensitivity analyses to evaluate the results are provided to obtain better insight and access to different aspects of the problem.

Keywords: supply chain master planning; financial-material flow; multi-objective; improved multi-choice goal programming.

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1. Introduction

In the last decades, integrated supply chain management models have gained much attention. Comprehensive supply chain planning developed models contain different parts of the supply chain like procurement, production, and distribution, which have been used in most recent studies. These models decrease the spreading of sudden and unpredictable problems in the supply chain and significantly the financial advantages of the chain's members will be affected (Guillen et al., 2007). The integrated models can reduce broadening the unpredictable events in the supply chain, which affects financial issues. Supply chain master planning (SCMP) determines the amounts and capacities of flows in a supply chain. Supply chain planning (SCP) integrated problems over the comprehensive planning of some functional areas and financial flows. Financial and functional parts, that are two important situations in an integrated supply chain, should be considered simultaneously to bring an appropriate integration (Gupta & Dutta, 2011).

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Also, the sub-optimality of the plans is prevented while interacts among different jobs and flows are considered simultaneously. Correlations among financial and material parts require by supply negotiators to cooperate parts of the chain. During the supply chain, the material goes from upstream to downstream but is flowing from downstream to downstream. In the supply chain, money receives from the downstream partner and transfer it to the upstream partner, and our purpose in this research is to identify the major centers of financial flow in the supply chain. In this paper, an integrated supply chain master planning under material-financial flows consideration is proposed. This research investigates the cash flows of members of the supply chain and focuses on mathematical modeling in the financial aspect of the chain to maximize the profit and minimize the price; thus, tactical decisions considering the material and financial flows in a supply chain have been made. Some suppliers, multi-center manufactures, and various customers are considered. Delays in deliveries and payments are accepted which is mentioned in contracts. Exchange payments and material deliveries influence the cash flow and functional acting of members. Moreover, lateral movement is permitted from manufacturing centers. Also, centers send their products to markets directly by ignoring the distribution sections. Furthermore, using debts and marketable securities is allowed for manufacturing centers and delay in payments causes penalties. Significantly, financial tools like debts and marketable securities that companies want to develop investments to reduce risks in changeable economies are allowed. To show the effects, two conflicting objectives of the chain's members' cash flow are considered. The model maximizes the net present value of suppliers and manufacturing centers. The third objective results the minimum market price of the final product. To transformation of the multi-objective model to its single one, improved multi-choice goal programming (IMCGP) method (Jadidi et al., 2015) is used. Then, the model solved in LINGO 17 to achieve optimized solutions and sensitivity analyses.
The paper goes on with the literature review in section 2 to discuss the last studies. In section 3, problem definition is described, 4th explains the solution approach and procedure. Section 5 illustrates an example and sensitivity analysis. The last one, section 6, includes conclusions and suggestions for further works.

2. Literature review

Some previous literature in supply chain master planning, material-financial supply chain, and multi-objective supply chain are explained in three separate sections.

2.1. Supply chain master planning

Master planning problems make strategic decisions in supply chain planning. There are some studies in this area that illustrated in this section. Dallasega et al. (2019) presented a mathematical model for agile scheduling in centralized production planning and control that considers long-term decisions and used the discrete event simulation model. Ehrenstein et al. (2019) considered extreme events in supply chains through strategic planning. They investigated weather and climate change's effects in chemical supply chains by developing a multi-objective model. The AUGMECON method was applied to solve the problem. Govindan and Cheng (2018) presented a supply chain planning with a stochastic programming and robust optimization approach. Also finding risk reduction uncertainty situations and problems are investigated in this study. Supply chain resilience is investigated in Kim and Bui's (2019) study. They focused on island ports and risk mitigation in strategic actions on supply chain. Vafaeenezhad and Tavakkoli (2016) studied supply chain master planning by introducing a multi-objective model with fuzzy variables for wood industry. Effect of customer willings and empowering technologies in grocery retail supply chain planning by cost focusing addressed in Vallandingham et al. (2018).

Yang et al. (2019) addressed a supply chain master planning which includes iron and steel investment in blockchain strategic planning. Zhou et al. (2019) developed a stochastic programming supply chain in coal-to-liquids problem to optimize energy arrangement and the profit of the chain. Akbarian-Saravi et al. (2019) proposed a comprehensive model for a bioethanol strategic and tactical planning in a sustainable supply chain. Liquefied gas's sales management was investigated by Sangaiah et al. (2019). They solve the proposed supply chain by metaheuristic methods to minimize the seller's cost.

2.2. Material-financial supply chain

Physical and financial issues in the supply chain were studied by some researchers that consist of financial flows and cash flow in the supply chain and considering material flows. In Aigbedo's (2019) study, the effect of these variables on the environmental aspect, impact on industrial products supply chains with assessing relevant factors. Cho et al. (2019) investigated the effects of bargaining on supply chain financial performance using regression analysis. A supply chain with financial decisions and constraints addressed by Huang et al. (2019) in controlling risk context and contract models. Lan and Zhong (2016) assessed a financial report of a supply chain by an evaluation model based on the DEMATEL-ANP (DANP) method. The penalty in a supply chain with supply disruption in a single-period model has been investigated by Li et al. (2015). Liu and Wang (2018) proposed an equilibrium model for strategic financial hedging supply chain networks. Mohammadi et al. (2017) developed an integrated financial-operational approach in designing a supply chain. Designing of a closed-loop model proposed by Polo et al. (2018). They introduced a robust optimization model under uncertainty conditions that integrate financial parts. The impact of flows in a supply chain to improve markets is presented by Puche et al. (2019). The noise's impact on financial result of Kanban has been analyzed. Rajabion et al. (2019) presented a model to evaluate the effects of the business processes of SCM systems for agricultural products' distribution in a green supply chain network. Tseng et al. (2019) studied the impacts of finance and costs improvement in a sustainable supply chain. Wang and Huang (2018) integrate operational and financial strategies for a capital-constrained global SCND by proposing a mathematical model. Yu et al. (2019) studied the impacts of financial performance and a supply chain's resilience. Rowshandel et al. (2019) used some of the most important characteristics of companies, namely cash assets, dividend rates and free cash flow of equity stocks and analyzed the equity forecast of statistical analysis. A case study is given in the Tehran Stock Exchange. Arab Momeni et al. (2019) addressed a three-level supply chain for an inventory model which involves manufacturer and retailer dependent on stock demand and price and capacity constraints. Ghasemy Yaghin (2019) proposed a production planning model to integrate a three-level marketing supply chain. A joint price differentiation to maximize the profit is investigated.

2.3. Multi-objective supply chain models

In a supply chain, some problems have several goals that should be optimized simultaneously. There are some methods to convert these multi-objective problems into a single-objective model. Doolun et al. (2018) presented a multi-objective model for a location-allocation decision to optimize three objectives that minimizing the total cost, maximizing the interest rate and minimizing the CO2 emissions, and used some metaheuristic algorithms to solve the problem. Ebrahimi (2018) developed a multi-objective location-allocation-routing model in a stochastic sustainable supply chain regarding discounts. He used ε-constraint method to solve the problem. A multi-objective model in green stochastic supply chain was addressed by Fathollahi Fard and Hajiaghaei-Keshteli (2018). Also, they used the ε-constraint method. Fathollahi Fard et al. (2018) proposed a closed-loop stochastic network in a social multi-objective model.

Ghaderi et al. (2017) used a possibilistic approach in a bioethanol robust multi-objective model. A simulation-optimization model was addressed by Avci and Selim (2017) in an inventory supply chain management. Habibi et al. (2017) developed a bi-objective supply chain in a multi-period model for blood in disaster and used goal programming model to solve. A multi-objective game and application in supply chain competition with linear programming developed by Ji et al. (2018). A possibilistic approach in a multi-objective closed-loop model in battery industries is illustrated by Tosarkani and Amin (2018). For solving the model, they used the ε-constraint method. To design an optimal multi-objective network, a tabu search-based algorithm presented by Mohammed and Duffuaa (2019). Mohammed et al. (2018) presented a hybrid MCDM-fuzzy method by fuzzy multi-objective model and the ε-constraint was applied to find Pareto optimal solutions and then TOPSIS method was applied to choose the final Pareto solution. Mohebalizadehgashti et al. (2020) introduced a meat supply chain and augmented ε-constraint was applied to solving the multi-objective problem. Niu et al. (2019) proposed a cooperative bacterial foraging optimization method with a multi-objective model. They used metaheuristic algorithms to solve the problem. Pariazar and Sir (2018) presented a multi-objective model with disruptions using genetic algorithms. A closed-loop model in green supply chain optimization investigated by Rad and Nahavandi (2018) by a multi-objective model. Paydar et al. (2017) considered risk collection to develop a closed-loop engine oil supply chain. They used augmented ε-constraint to convert the bi-objective model. Resat and Unsal (2019) proposed a multi-objective model in packaging industry at a sustainable supply chain and solve it with augmented ε-constraint. Roghanian and Cheraghalipour (2019) developed metaheuristic methods to transform the multi-objective problem in a citrus closed-loop supply chain include carbon emissions. A new method called integrated fuzzy MOORA method and another one is the FMEA technique was proposed by Arabsheybani et al. (2018) for selecting suppliers including risk and quantity discounts in the sustainable supply chain. Rohmer et al. (2018) presented a food supply chain and analyzed it with a multi-objective model. A multi-objective and metaheuristic model was introduced by Tautenhain et al. (2018) to design and plan sustainable supply chain. Wheeler et al. (2018) introduced a multi-objective biomass supply chain by combining the MADM method. Rezaei et al. (2019) developed a supply chain network to manage customer relationships in a multi-objective model. They solve it by the improved multi-choice goal programming method. Tirkolaee et al. (2020) considered three aspects of sustainability to help companies obtain their targets. The goal programming and Fuzzy methods are used to solve the problem. Mardani (2020) presented a summary of some sustainable related articles and found some reasons and theories in the previous studies.

2.4. Research gap

According to the studies reviewed, so far most papers have examined the financial or physical impacts separately in the supply chain, while the two have interactions and need to be examined together. Many of these papers couldn't propose a comprehensive prospect of the supply chain that focused on one particular aspect. The connection between physical and financial flows should be done by contracts but has been overlooked in most research. Since delays in payment in the real world are inevitable, it must be taken into account. The objective function of other research has focused on the cash flow of central companies, but the supply chain members' cash flow can influence each other. So, the cash flow of members should be optimized simultaneously with multi-objective planning.

3. Problem definition

A multi-objective model for procurement-production planning is proposed for an integrated supply chain. Some suppliers and multi-center manufacturers are considered in a three-level supply chain. Raw materials are supplied by a specified supplier and suppliers can supply one kind of raw material. Products are transported to the customer by centers without the distributor's channel. The schematic of the aforementioned network is shown in Fig.1. For formulating the proposed model, some assumptions are considered as follow:

- Manufacturing centers could have lateral trans-shipment to prevent shortage between manufacturing centers and attaining an effective plan for transportation when answering the customer's demands. Though, when there are demands over/under predicted one in some periods, manufacturing centers exchange their deficit or the surplus amount by other manufacturing centers so that the total inventory costs may decrease.
- Outsourcing is allowed also for manufacturing centers as an option is a tool to tackle market uncertainties.
- The cost of raw material by manufacturing centers could be paid and a delay for products that are transported to the suppliers and other centers may occur. However, a specified penalty is considered for delayed payments.
- To support the operations of manufacturing centers, they are permitted to use debts up to a specified amount.
- In order to manufacture center interest rates for repayments, decisions among the repayment of debts are made for it.
- Marketable securities as an appropriate financial tool are used to provide the financial contribution of centers.
- Market price, investment, and sold expanses of marketable securities are considered as the decision variables.

The developed model focused on determining the production, inventory, outsourcing, and reverse amounts of centers, inventory and reverse amounts of suppliers, the quantity of transportation flows in the centers, center and supplier's cash flow, cost of raw material for centers and cost of transportation flow among two centers, the number of debts, and transactions and sold quantity of marketable securities. This problem finds out these factors by considering maximizing the NPV of centers' cash flows and also for suppliers, and minimizing the market price. Some notations of the aforementioned model are shown as follows:

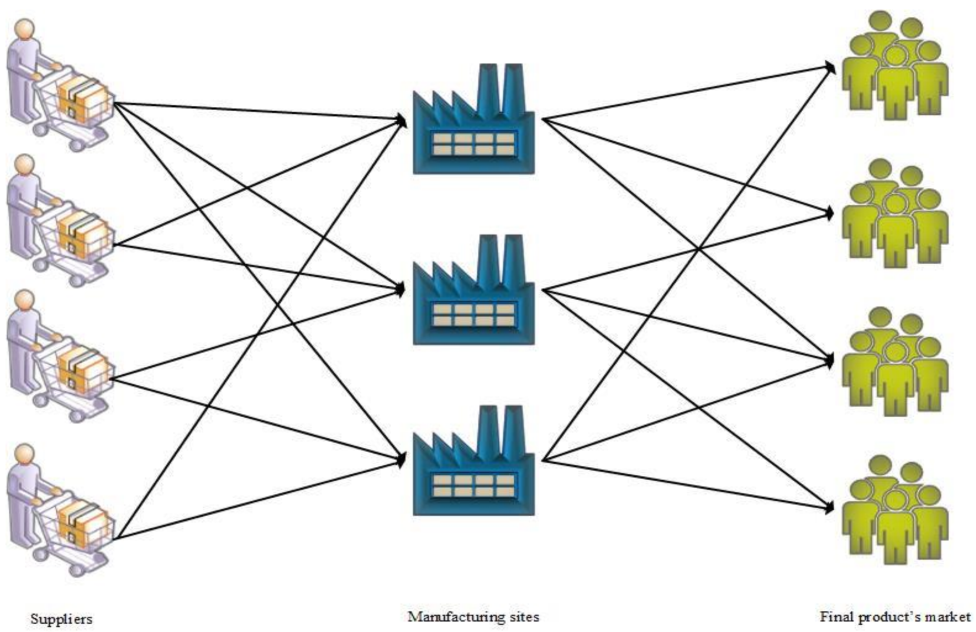

Figure 1. The schematic of the aforementioned network

Indices

- r Index of raw material
- s Index of the manufacturing center
- p Index of the final product
- t Index of the time period

Parameters

D_{spt}	Demand of the product p to center s in time t
CRM_{rt}	The unit price of the raw material r for the supplier in time t
H_r	Holding cost for supplier r in each period
FD_{sp}	Backorder cost of the product p in center s
I	Risk-free interest rate
α_{rp}	Conversation rate for raw material r to product p
J	The added rate for delays in payments
IN	The interest rate of debt
FS_{sp}	The production cost of the product p to center s
FO_{sp}	Outsourcing cost of the product p to center s
HI_{sp}	Holding cost of the product p in center s
CM_r	The unit cost of the raw material r for each center
$CT_{pss'}$	Transportation cost of the product p among center s and s'
$ZP_{tt''}$	Profit coefficient obtained from marketable securities
$ZI_{tt''}$	Cost coefficient of marketable securities and finances
DU	Ceil level of debts of center
MI_s	Ceil stock level of center s
CS_{st}	The production capacity of center s in time t
Pr_{sp}	Production time of product p in center s
CFL	Least cash flow permitted for center s
CSL	Least cash flow permitted for suppliers
B_{st}	Initial rate of marketable securities of the center s in time t

Decision Variables

BO_{spt}	Outsourcing amount of product p at the center s in time t
I_{spt}	The stock level of product p in center s at the ending of time t
X_{spt}	Production volume of product p in the center s in time t
$X_{s'spt}$	Transportation amount of product p of center s' to center s over time t
T_{rst}	Transported raw material r of the supplier to center s in time t
XO_{rt}	Raw material r bought by the supplier in time t
MRP_{spt}	The market price of product p at the center s in time t
CF_{rt}	Net cash flow of the supplier r in time t
IO_{rt}	The stock level of raw material r at the ending of time t
$CP_{st't}$	Quantity of money paid in center s in time t to pay back in time t'
PD_{st}	Cash of debts in the center s in time t
N_{st}	Net cash flow of center s in time t
$CPS_{s'spt't}$	Money paid by the center s' to center s in time t for raw material r bought in time t'
$W_{srtt'}$	Money paid that center s paid to supplier r for raw material r bought in time t'
CFS_{st}	The net cash flow of marketable securities achieved at center s in time t
$CI_{st''t}$	Marketable securities investment of center s in time t up to time t''
$V_{st''t}$	Achieved cash of marketable securities that center s sold in time t up to time t''

Objective functions

$$Max\ \ Z_1 = \sum_s \sum_t \left(NS_{st} (1+I)^{-t} \right) \tag{1}$$

$$Max\ \ Z_2 = \sum_r \sum_t \left(CF_{rt} (1+I)^{-t} \right) \tag{2}$$

$$Min\ \ Z_3 = \sum_s \sum_p \sum_t MRP_{spt} D_{spt} \tag{3}$$

Objective functions (1), (2), and (3), show the maximum of the net present value of the manufacturing centers' cash flow and the cash flow of suppliers and minimizes the market price of the final product simultaneously.

Constraints

$$BO_{spt} + X_{spt} + I_{spt-1} - I_{spt} + \sum_{s'} \left(XT_{s'spt} - XT_{ss'pt} \right) - BO_{spt-1} + BO_{spt} \ge D_{spt} \qquad \forall s,p,t \tag{4}$$

$$XO_{rt} + IO_{t-1} - IO_{rt} \ge \sum_s T_{rst} \qquad \forall s,p,t \tag{5}$$

$$CF_{rt-1}\left(1+I\right) - CF_{rt} - H_r IO_{rt} + \sum_s \sum_{t'} W_{rst't} \ge CM_r XO_{rt} \qquad \forall r,t \tag{6}$$

$$X_{spt} \le \sum_r \alpha_{rp} T_{rst} \qquad \forall s,p,t \tag{7}$$

$$\begin{aligned} & CFS_{st} + PD_{st} - \sum_{t'} CP_{st't} + \sum_p MRP_{rst} D_{spt} + \left(1+I\right) N_{st-1} - N_{st} + \\ & \sum_{s'} \sum_{t'} \sum_p \left(CPS_{s'spt't} - CPS_{ss'pt't} \right) - \\ & \sum_p \left(F_{sp} X_{spt} + FO_{sp} BO_{spt} + HI_{sp} I_{spt} + Fd_{sp} BO_{spt} \right) \ge \sum_r \sum_{t'} W_{rst't} \end{aligned} \qquad \forall s,t \tag{8}$$

$$\sum_{t>t'} W_{rst't} \left(1+J\right)^{-(t-t')} = T_{rst'} CM_r \qquad \forall r,s,t' \tag{9}$$

$$\sum_{t>t'} \sum_p CPS_{s'spt't} \left(1+J\right)^{-(t-t')} = \sum_p XT_{s'spt'} CT_{pss'} \qquad \forall s,s',t' \tag{10}$$

$$\sum_{t>t'} CP_{st't} \left(1+IN\right)^{-(t-t')} = PD_{st'} \qquad \forall s,t' \tag{11}$$

$$PD_{st} \le DU \qquad \forall s,t \tag{12}$$

$$\sum_p I_{spt} \le MI_s \qquad \forall s,t \tag{13}$$

$$\sum_p \Pr_{sp} X_{spt} \le CS_{st} \qquad \forall s,t \tag{14}$$

$$N_{st} \ge CFL \qquad \forall s,t \tag{15}$$

$$CF_{rt} \ge CSL \qquad \forall r,t \tag{16}$$

$$CFS_{st} \le B_{st} - \sum_{t''>t} CI_{st''t} + \sum_{t''>t} V_{st''t} + \sum_{t<t''} CI_{stt''} \left(1+ZP_{tt''}\right) - \sum_{t''<t} V_{stt''} \left(1+ZI_{tt''}\right) \qquad \forall s,t \tag{17}$$

$$BO_{spt}, X_{spt}, I_{spt}, XT_{s'spt}, T_{rst}, XO_{rt}, IO_{rt} \ge 0 \text{ and integer} \qquad \forall r,p,s,s',t,t',t'' \tag{18}$$

$$CF_{rt}, PD_{st}, CP_{st't}, N_{st}, CPS_{s'spt't}, W_{srtt'}, CFS_{st}, CI_{st''t}, V_{st''t} \ge 0 \qquad \forall r,p,s,s',t,t',t'' \tag{19}$$

Constraint (4) controls the stock level of centers. Constraint (5) controls the stock level of suppliers. Constraint (6) compares the cash flow of suppliers in different periods though the financial and the material flows are considered in the supply chain. Constraint (7) presents the transformation of the raw material to the final products. Constraint (8) represents the cash flow balance for centers that ensures converting cash flow of the earlier time to the present time. Constraint (9) ensuring the cost of raw materials by cash flow taken by suppliers, and there is an assumption that delayed payments inclusive the penalties, according to the delay time. Constraint (10) is like to constraint (9) but is about transportations. The interest rate of the banks is added for debts at different times is mentioned in constraint (11). Constraint (12) calculates an upper bound for the debts that manufacturing centers allowed to use in each period. Constraint (13) and (14) shows the production capacity and inventory holding. Constraints (15) and (16) present the minimum amounts of cash flows that centers and suppliers are allowed to use. Buying or selling marketable securities in each period. Constraint (17) indicates the profit gain of marketable securities by considering equity between the new finances and sold cost of them. Constraints (18) and (19) explain the types of decision variables.

4. Solution approach

One of the most important multi-objective approaches is the goal programming method, proposed by Charnes and Cooper in 1961. The importance of these techniques is that several goals could be considered simultaneously. This method has been aimed at minimizing deviations from goals. Though, it is a flexible method for decision making. To solve the proposed multi-objective model, the improved multi-choice goal programming (IMCGP) that presented by Jadidi et al. (2015) is used to convert it to a single objective one here. Because IMCGP considers a goal interval instead of a single goal. Sometimes the value of the objective function may go beyond the expectation, which is not in other models, which may result in fines for the model. IMCGP is a connection of revised goal programming and considering the range of goal's aspiration level. The achieved value of objective might be more than the goals, that other goal programming methods ignored it. In this method, the weight of each objective is given and based on those formulated a new objective. Then, the single objective model will solve with commercial solvers. The new objective function is as equation (20), and those three functions will be added to constraints with a specified value. Some new constraints as equations (21)-(27), respect to these deviations are also added.

$$Max\sum_{k=1}^{3}(W_k^{\alpha}\alpha_k - W_k^{\beta}\beta_k) \tag{20}$$

Subject to:

$$f_k(x) = \alpha_k g_k^{+} + (1-\alpha_k)g_{k,\min} + \beta_k(g_k^{-} - g_{k,\min}) \qquad k = 1,2 \tag{21}$$

$$f_k(x) = \alpha_k g_{k,\min} + (1-\alpha_k)g_{k,\max} + \beta_k(g_k^{-} - g_{k,\max}) \qquad k = 3 \tag{22}$$

$$h_i(x) = (\le or \ge)0 \qquad i = 1,2,...,n \tag{23}$$

$$\alpha_k \le y_k \le 1+\alpha_k \qquad k = 1,2,3 \tag{24}$$

$$\beta_k + y_k \le 1 \qquad k = 1,2,3 \tag{25}$$

$$y_k \in \{0,1\} \qquad k = 1,2,3 \tag{26}$$

$$0 \le \alpha_k, \beta_k \le 1 \qquad k = 1,2,3 \tag{27}$$

y_k is a zero-one variable, W_k^{α} and W_k^{β} are the weights of each objective, $g_{k,\min}$ and $g_{k,\max}$ represent the *k*th goal's aspiration level, g_k^{-} and g_k^{+} show the objective function's value, α_k, β_k are coefficient in the range of $[0,1]$, and $h_i(x)$ are the model's primary constraints.

5. An industrial example

The proposed model is assessed with an industrial example to show the accuracy of the model. First, some numerical data are illustrated, then the results and sensitivity analyses are demonstrated.

5.1. Input parameters and results

An industrial example concluding 2 products, 4 raw materials, 3 manufacturing centers, and 5 time periods are considered. This MILP model included 1372 variables, 268 integer variables, and 325 constraints. This model can be used in different industries. Some important parameters and results are given in Tables 1 to 8 to have a better demonstration of the model and results. Table 1 shows the demand for product *p* that received by manufacturing center *s* in period *t*. Tables 2 and 3 are the conversation rate of product *p* by raw material *r*, and the unit price of raw material *r* in each period. Table 4 shows the backorder cost of product *p* in manufacture *s*, outsourcing, and holding costs.

The model solved in LINGO 17 on an Intel (R) Core i5 CPU 2.50 GHz computer with 8 GB of RAM in 20 seconds. Tables 5-8 show some results of the model that are more impressive in objective functions. Table 5 is the quantity of production. Table 6 is the amount of raw material *r* transported in time *t* by the supplier to center *s*. Tables 7 and 8 are the net cash flow of suppliers and manufacturing centers.

Table 1. Demand for products

D_{spt}	Time				
(s,p)	t_1	t_2	t_3	t_4	t_5
1.1	11	16	10	12	8
1.2	5	9	14	6	3
2.1	12	16	4	3	9
2.2	18	5	2	8	10
3.1	9	7	6	10	12
3.2	14	15	12	5	9

Table 2. Conversation rate

α_{rp}	p_1	p_2
r_1	5	8
r_2	9	6
r_3	7	10
r_4	4	3

Table 3. The unit price of raw materials

CRM_{rt}	t_1	t_2	t_3	t_4	t_5
r_1	10	11	16	14	12
r_2	9	12	14	13	15
r_3	11	8	9	10	16
r_4	14	12	8	7	5

Table 4. Backorder cost, outsourcing cost, and holding cost

	FD_{sp}		FO_{sp}		HI_{sp}	
Supplier/ Product	p_1	p_2	p_1	p_2	p_1	p_2
s_1	2	3	3	5	1	3
s_2	2	2	4	7	1	4
s_3	1	1	5	8	3	5

Table 5. Production volume

X_{spt}	Time				
(s,p)	t_1	t_2	t_3	t_4	t_5
1.1	15	20	8	14	15
1.2	12	15	8	19	10
2.1	11	7	18	16	13
2.2	14	25	18	14	9
3.1	5	12	8	15	12
3.2	17	19	22	18	15

Table 6. Transported amount of raw material

T_{rst}	Time				
(r,s)	t_1	t_2	t_3	t_4	t_5
1.1	10	6	11	14	9
1.2	7	15	13	4	10
1.3	11	17	14	8	18
2.1	16	13	5	11	8
2.2	9	12	10	6	17
2.3	15	18	4	17	11
3.1	14	9	13	10	9
3.2	11	7	13	14	18
3.3	15	14	9	5	11
4.1	12	17	13	10	5
4.2	15	12	16	11	6
4.3	13	16	12	7	19

Table 7. Net cash flow of suppliers

CF_{rt}	t_1	t_2	t_3	t_4	t_5
r_1	60	57	62	53	51
r_2	65	69	64	67	63
r_3	55	58	53	61	59
r_4	52	58	56	60	63

Table 8. Net cash flow of centers

N_{st}	t_1	t_2	t_3	t_4	t_5
s_1	82	80	84	78	81
s_2	74	78	81	83	76
s_3	77	79	80	84	82

5.2. Sensitivity analyses

To get a better vision of the results and being more useful, sensitivity analysis of the objective functions with efficient parameters are shown in Tables 9 to 11. Analyzing the interest rate on debt and risk-free interest rates are presented in Tables 9 and 10, respectively. Also, the comparison between different risk-free interest rates is shown in Fig.2. The effects of different amounts of these parameters show the best value of them and the difference between each objective function's value in those quantities. Table 11 demonstrates the analysis of different weights of objective functions in transforming of the multi-objective model. It shows each objective function's quantity in each weight and the single objective model's value in those weights. Which provides the best weights and solutions.

According to Table 9, the best rate is in %10 that two first objective functions are maximized and the third one is minimized. In Table 10 and Fig.2, the comparison of different rates is given, which shows each objective function separately beside the other one. Table 11 shows the different weights of objective functions, which the best weight, that maximizes two first objective functions (members' cash flow) and minimizes the third one (market price), are 0.45, 0.45, 0.1 respectively.

Table 9. Sensitivity analysis of the interest rate on debt

IN	Z_1	Z_2	Z_3
10	199.35	199.15	20372.63
15	198.74	198.67	20738.44
20	198.64	198.34	20843.53
22	198.25	197.68	21384.43
25	197.95	197.45	21573.54
30	197.94	196.36	21935.25

Table 10. Sensitivity analysis of the risk-free interest rate

I	Z_1	Z_2	Z_3
0	199.68	199.21	20472.48
0.1	198.14	198.42	21164.83
0.2	197.57	197.97	21382.23
0.3	197.34	197.83	21492.10
0.4	196.23	195.26	22258.42

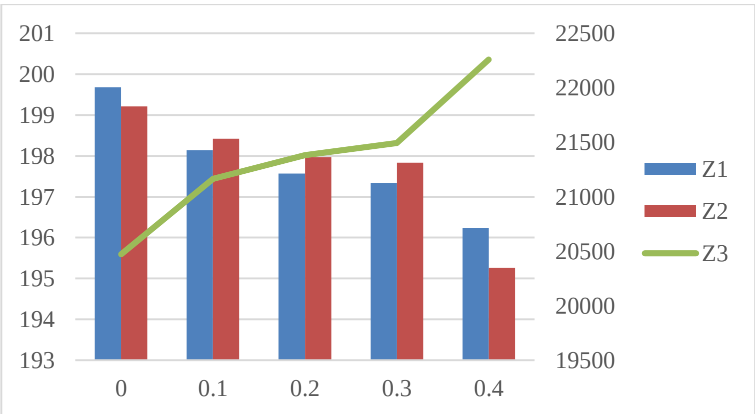

Figure 2. The comparison of the different risk-free interest rates

Table 11. Sensitivity analysis of the weights of the objectives in the solution approach

W_1	W_2	W_3	Z_1	Z_2	Z_3	*IMCGP*
0.2	0.2	0.6	196.45	195.36	18674.33	1.23
0.3	0.3	0.7	197.86	196.62	19163.22	1.11
0.4	0.4	0.2	199.63	199.25	20274.14	1.34
0.45	0.45	0.1	200.87	200.43	21358.42	1.27

5.3. Managerial insight

This study has developed an integrated model that presents a comprehensive production-planning supply chain over the medium term. It calculates the problem of financial and material flows. As such, SCMP will help integrating production and supply tactical plans into a supply chain while considers for both the physical and financial flows of chain members, using delayed payment mechanisms and performance permits the interactions between material and financial flows while maximizing cash flows from manufacturing centers and suppliers as opposing objectives.

Lowering the rate of absorption can help improve the supply chain. Thus, by lowering interest rates on banks, communities can improve the performance of their production companies from a financial and physical point of view. It also contributes more importance to the chain members' cash flow than the market price, which contributes to the better performance of the whole complex.

6. Conclusion

In this study, an SCMP problem was investigated that integrates procurement and production systems, which are calculated in material and financial flows. A multi-objective model optimizes the material flow amounts of money that must be shared among suppliers and manufacturing centers. The aim of the model is to maximize the two first conflicting objectives and minimizing the market price of final products. IMCGP applied to convert the multi-objective problem to a single objective model. The proposed model consists of a mathematical model which is suitable for use in industries and some markets. Results show the best risk-free interest rate, the interest rate on debt, and the best weights of objective functions.

There is a considerable lack of researches in integrated material-financial planning. Thus, the financial flow should be considered in supply chains, so that affects all parts of the chain. Moreover, some other contracts, different investment opportunities, and different financing methods can be used in these problems in further studies. Also, metaheuristic algorithms could be used for large scale problems.

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